

IV. Governador Valadares

Clinopyroxenite, 158 grams

find



Figure IV-1. Photograph of Governador Valadares (158 grams) from Dr. Fernanda Ferrucci via Dr. Giuseppe Cavarretta. Photo taken by L. Spinozzi.

Introduction

A well-preserved individual stone of 158 grams was found in 1958 near Governador Valadares, in Minas Gerais, Brazil. The single specimen appears shiny and well preserved, although extremely brittle (figure IV-1); these characteristics led Burragato *et al.* (1975) to conclude that it must have been collected a short time after the fall. The sample is almost completely covered by a black, glassy, fusion crust (Gomez and Keil, 1980). It was classified as a nakhlite by Burragato *et al.* (1975).

Petrography

Governador Valadares is a clinopyroxenite petrologically very similar to Nakhla (Burragato *et al.*, 1975, Berkley *et al.*, 1980, Mikouchi and Miyamoto, 1997). The thin section (figure IV-2) shows a porphyritic texture with large augite phenocrysts embedded in a fine-grained mesostasis made up of glass and semi-radiating skeletal crystals of Fe-rich pigeonite, plagioclase, K-feldspar, silica, apatite, magnetite and sulfides. The elongate pyroxene phenocrysts are weakly aligned (Berkley *et al.*, 1980). Rare Fe-rich olivine is also present.

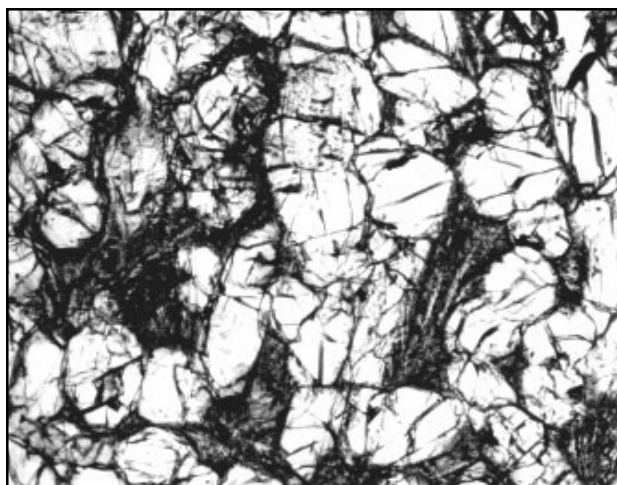


Figure IV-2. Photomicrograph of thin section #479 of Gobernador Valadares from University of New Mexico. Field of view 2.2 mm.

The olivine in Gobernador Valadares contains magmatic inclusions which have been used by Harvey and McSween (1992d) to estimate the composition of the parental melt.

Mineral Chemistry

Olivine: Olivine grains (Fa_{67}) up to 2 mm in size are found in Gobernador Valadares (Berkley *et al.*, 1980). A second generation of smaller, more Fe-rich (Fa_{77}), olivine grains are found with plagioclase in the mesostasis (Berkley *et al.*, 1980). The olivine in nakhlites has higher Fe/Mg than that of coexisting pyroxene. The olivine in Gobernador Valadares is zoned in composition with steep Fe/Mg profiles in the core regions and progressively flatter toward the crystal boundaries (Harvey and McSween, 1991). Mikouchi and Miyamoto (1997) reported fine lamellae of symplectite (augite and magnetite) in olivine (*similar to Nakhla*).

Clinopyroxene: Augite is the major mineral in Gobernador Valadares. Clinopyroxene grains are elongate with an aspect ratio of 3:1. Berkley *et al.* (1980), Harvey and McSween (1991) and Mikouchi and Miyamoto (1997) have studied the zoning in clinopyroxene in Gobernador Valadares. They find that the cores are homogeneous with zoning towards Fe-enrichment at the rims, with relatively steep transition zones in between (figure IV-3). The average composition of the augite is $Wo_{38.5}En_{38.9}Fs_{22.6}$ (Berkley *et al.*, 1980).

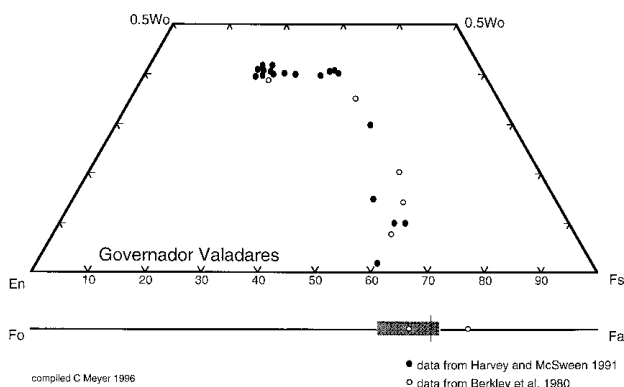


Figure IV-3. Composition diagram of pyroxenes and olivines in Gobernador Valadares. Data compiled from Harvey and McSween (1991) and Berkley *et al.* (1980).

Plagioclase: Gomez and Keil (1980) report the composition of plagioclase in Gobernador Valadares as $Or_{2.9}Ab_{48.3}An_{48.8}$.

Iddingsite: A reddish mixture of smectite clay and hydrous iron oxides, occurs on the rims or penetrates most olivine grains in Gobernador Valadares, as it does in the other nakhlites (Gooding *et al.*, 1991a, Treiman *et al.*, 1993).

Amphibole: Harvey and McSween (1992d) reported a Ti-rich amphibole in a magmatic inclusion in olivine in Gobernador Valadares.

Magnetite: Harvey and McSween (1992d) found Ti-rich magnetite in melt inclusions in olivine in Gobernador Valadares. Berkley *et al.* (1980) reported ilmenite lamellae in the magnetite.

Symplectite: Mikouchi and Miyamoto (1997) have reported thin lamellar symplectic inclusions composed of augite and magnetite in host olivine.

Spinel: Harvey and McSween (1992d) reported Fe, Al spinel in melt inclusions in olivine in Gobernador Valadares.

SiO₂: Pure SiO₂ is reported in minor amounts in Gobernador Valadares and Nakhla, but not in Lafayette (Berkley *et al.*, 1980).

Sulfides: Berkley *et al.* (1979, 1980) reported minor pyrite, troilite and chalcopyrite in the mesostasis.

Table IV-1. Composition of Governador Valadares.

	Burragato75	Mittlefehldt96
weight		26.59 mg
SiO ₂ %	49.52	
TiO ₂	0.35	
Al ₂ O ₃	1.74	
Fe ₂ O ₃	1.14	
FeO	18.62	19.5 (a)
MnO	0.67	
CaO	15.82	15 (a)
MgO	10.92	
Na ₂ O	0.82	0.53 (a)
K ₂ O	0.43	0.18 (a)
P ₂ O ₃		
sum		
Li ppm		
C		
F		
S		
Cl		
Sc		57.4 (a)
V		
Cr	1437	1950 (a)
Co		47.7 (a)
Ni		80 (a)
Cu		
Zn		80 (a)
Ga		
Ge		
As		
Se		
Br		2.5 (a)
Rb		
Sr		80 (a)
Y		
Zr		
Nb		
Mo		
Pd ppb		
Ag ppb		
Cd ppb		
In ppb		
Sb ppb		
Te ppb		
I ppm		
Cs ppm		0.44 (a)
Ba		40 (a)
La		2.27 (a)
Ce		6 (a)
Pr		
Nd		
Sm		0.84 (a)
Eu		0.25 (a)
Gd		
Tb		0.12 (a)
Dy		
Ho		
Er		
Tm		
Yb		0.41 (a)
Lu		0.06 (a)
Hf		0.37 (a)
Ta		0.09 (a)
W ppb		
Re ppb		
Os ppb		
Ir ppb		
Au ppb		
Tl ppb		
Bi ppb		
Th ppm		0.15 (a)
U ppm		
technique	(a) INAA	

Glass: Interstitial glass has been found to be silica-rich (Berkley *et al.*, 1980).

Whole-rock Composition

Burragato *et al.* (1975) determined the bulk chemical composition (table IV-1) and noted that it was similar to the that of Nakhla. Mittlefehldt and Lindstrom (1996) reported that the REE pattern was similar to that of Nakhla and Lafayette, but that the FeO content was ~10% less.

Radiogenic Isotopes

Bogard and Husain (1977) determined a $^{39}\text{Ar}/^{40}\text{Ar}$ age of 1.32 ± 0.04 Ga (figure IV-4) - essentially identical to that of Nakhla and Lafayette (Podeseck, 1973). Wooden *et al.* (1979) reported a Rb-Sr age of 1.33 ± 0.01 Ga and Shih *et al.* (1996) determined a Sm-Nd age of 1.36 ± 0.03 Ga (figure IV-5). The low initial Nd value indicates formation from a light-REE-depleted source (Shih *et al.*, 1996, Harper *et al.*, 1995).

A terrestrial exposure age has not yet been determined.

Cosmogenic Isotopes and Exposure Ages

Bogard and Husain (1977) originally determined a cosmic-ray exposure age of 8 ± 1 Ma (figure I-11). Bogard *et al.* (1984b) calculate the exposure age to be about 9 Ma.

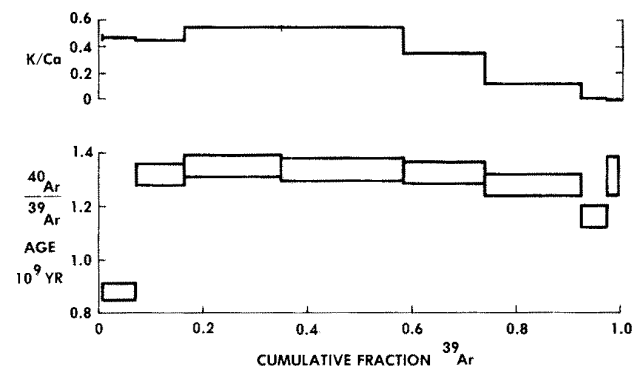


Figure IV-4. Argon plateau diagram for Governador Valadares meteorite from Bogard and Husain (1977). This is a copy of figure 1 in their paper in *Geophys. Res. Letters* 4, 69.

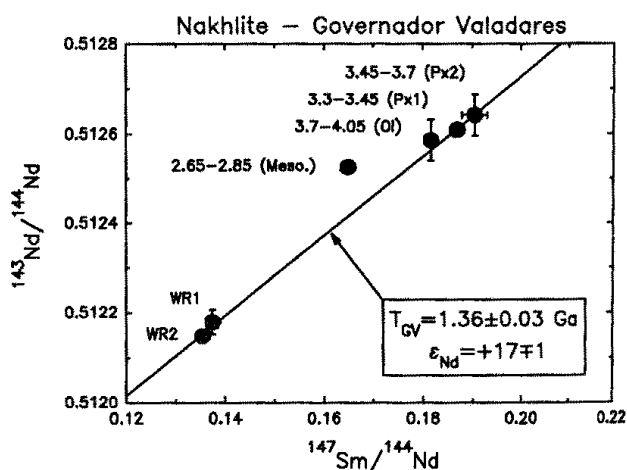


Figure IV-5. *Sm-Nd isochron diagram for Governor Valadares meteorite from Shih *et al.* (1996). This is figure 1 in their extended abstract LPS XXVII, page 1198.*

Other Isotopes

The carbon and nitrogen content and isotopic composition has been reported by Wright *et al.* (1992). Leshin *et al.* (1996) reported isotopic compositions of hydrogen from water and carbon and oxygen released from CO₂.

Harper *et al.* (1995) reported excess ¹⁴²Nd.

Processing

The Governor Valadares specimen was 'found' by a mineral hunter in 1958 (Gomez and Keil, 1980). The main mass (96 grams) is owned by Dr. Fernanda Ferrucci (Graham *et al.*, 1985, Cavarretta, *personal communication*). Thin sections can be borrowed from the University of New Mexico.

Figure IV-6 shows what is known about the distribution of pieces of Governor Valadares.

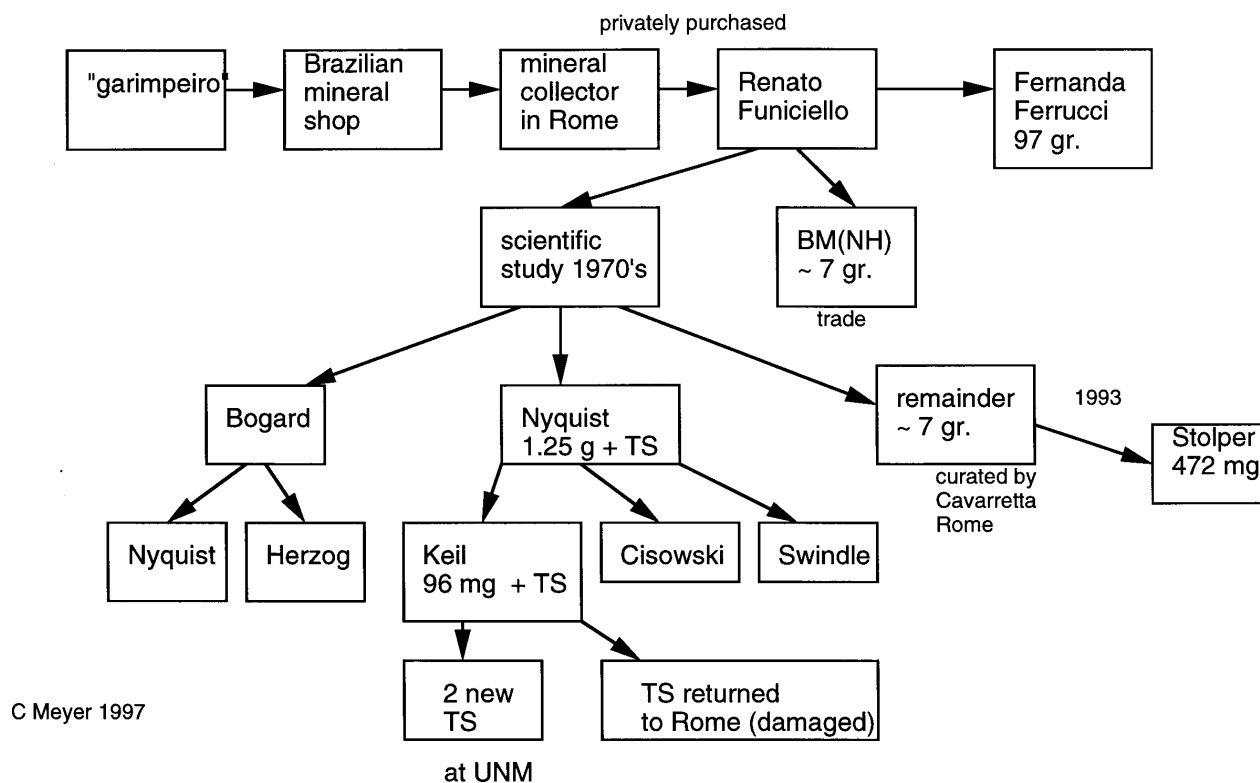


Figure IV-6. *Distribution of Governor Valadares.*